Electromechanical Actuator Testing at IPTD

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Electromechanical actuation technology is currently being investigated and is considered the likely candidate for future replacement of the hydraulic systems utilized in most aerospace actuation applications today. Marshall recently demonstrated the maturity of the electromechanical actuator (EMA) technology by integrating a simplex valve EMA into a system-level test of the Rockwell International X–33 Phase I Integrated Propulsion Technology Demonstrator (IPTD).

The Simplex Valve EMA used in this demonstration was originally designed for and tested as an EMA technology "proof of concept." The design (fig. 30) consists of a three-phase brushless motor that drives a 120:1 reduction harmonic drive. The harmonic drive is directly mated to the actuator output spline. Position feedback is provided by a resolver, which is mounted on the output of the harmonic drive. Breadboard control electronics for the EMA were developed by the Astrionics Laboratory. The electronics utilize both motor current and actuator position to provide actuator control. The actuator was designed to meet the performance requirements of the Space Shuttle Main Engine's main oxidizer valve (MOV) actuator. Several years after the EMA had successfully completed laboratory performance testing, MSFC's Propulsion Laboratory was provided with the opportunity to integrate this component into a higher systems level test.

Rockwell International and NASA under an X–33 Phase I task agreement developed a propulsion system test-bed (IPTD) for the demonstration and development of propulsion technologies and operations concepts. System level integration and operation of MSFC's EMA was identified as a viable test for IPTD. The actuator was installed on an SSME main fuel valve which had been integrated into a 4-in fill and drain line on the liquid hydrogen side of the propulsion module (fig. 31). The control electronics and the power source for the actuator were remotely located on the test stand to protect against the environment. The cable length from controller to actuator was approximately 40 ft. The actuator was remotely controlled from the blockhouse by the Rockwell Propulsion Checkout and Control System (PCCS), which also provided for remote monitoring of the position feedback during checkout and test.

Before testing, redlines were developed for operation of the EMA. The presence of the EMA introduced an order of magnitude increase in electrical power (100 Vdc/ 100 A) previously seen in the potentially explosive environment of the IPTD. Activation of the EMA was therefore based on the absence of hydrogen in the area. In addition, the actuator was bagged and purged with nitrogen to prevent hydrogen accumulation and moisture from entering the EMA or electrical connections. Temperature redlines were also set on the actuator to prevent overheating and damage to the motor. Motor current redlines were

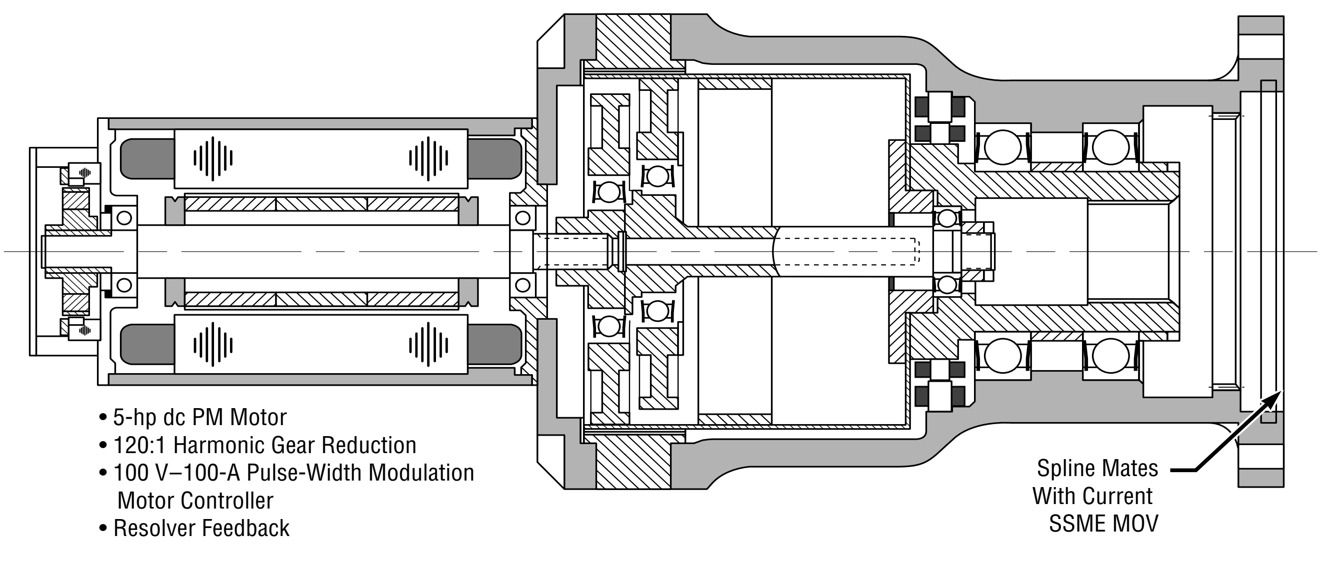

Figure 30.—MSFC Simplex Valve EMA.

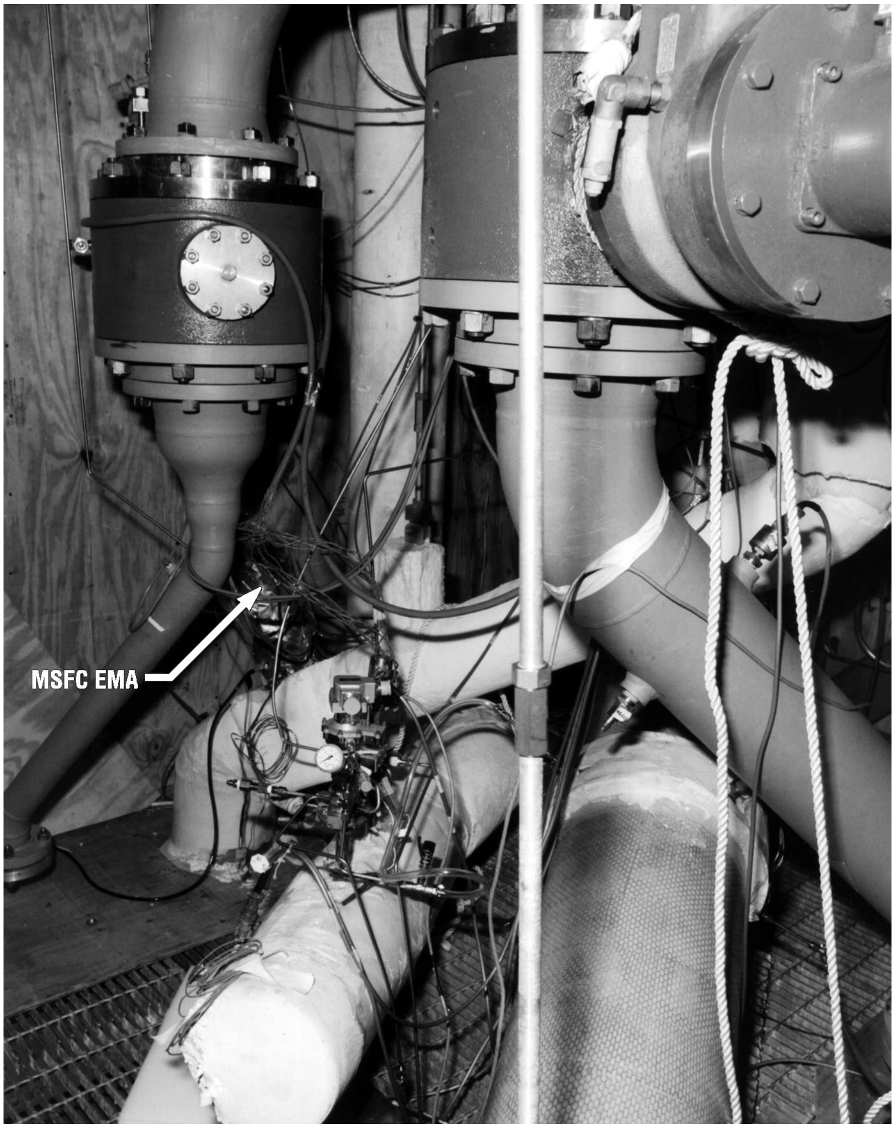

Figure 31.—EMA integrated into the IPTD.

also established. During actual test, position error was monitored in order to provide information for manual cut of actuator power from the blockhouse in case of actuator failure.

Actuator testing consisted of remotely cycling the actuator after liquid hydrogen (LH_2) cold shock of the system and later cycling during LH_2 flow (approximately 500 gal/min) using the PCCS. During actuator operation, the valve temperature was –130 °F. The EMA had not been designed for operation under the cryogenic condition presented by the presence of LH_2, and the possible reduction in performance due to temperature was a concern for these tests. Both a thermal isolator between the valve and EMA and a heater blanket around the throat of the EMA were utilized to alleviate performance degradation due to the environment. A similar procedure is followed on the SSME with the hydraulic actuator. During both the cold shock and flow tests, the actuator performed without anomalies, successfully demonstrating the EMA technology at a systems level, under cryogenic conditions.

Demonstration of this technology in a propulsion system environment was not the only benefit of these tests. A valuable integration and operations data base was generated which will be directly applicable to future testing and vehicle implementation of EMA's. Possible design improvements and considerations for operations in flight-type environments (such as placement of electrical components away from thermal paths and dry lubrication for cryogenic operations) were noted as well as integration and operation issues established for use in the design of EMA's and of the systems in which EMA's will be utilized.

Sponsor: Reusable Launch Vehicle Program

Biographical Sketch:
Rae Ann Weir is an electrical engineer in the Turbomachinery and Control Mechanisms Branch of MSFC's Propulsion Laboratory. She received a B.S. electrical engineering degree from the University of Tennessee in 1989. She has been employed by NASA since that time and has 7 years experience in the field of electromechanical actuators.